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Hydrochemical Evaluation of Water Quality and Trophic State Status of Saheb Bandh Lake, Purulia

Geetanjali Dutta[1], Srimanta Gupta[1*], Anuradha Mondol[1] and Priyabrata Mukherjee[2]
[1]Department of Environmental Science, The University of Burdwan,
[1*](Corresponding Author): Assistant Professor of Department of Environmental Science, The University of Burdwan, Email Id- srimantagupta@yahoo.co.in
[2]Teacher in Nistarini College Purulia, Department of Environmental Science, Sidho Kanho Birsha University

ABSTRACT: Saheb bandh lake is an important wetland ecosystem of Purulia district and is well known for its biological diversity, aesthetic beauty, recreation and multipurpose features. In the present study an attempt is made to evaluate water quality as well as trophic state status of the lake. Lake water is mostly of Mg-HCO_3 type. Relationship between different ionic ratios indicates that weathering of silicate minerals is generally considered to be the major source of alkalis in the lake water. Regarding drinking and irrigation water suitability criteria all the samples are moderately suitable. According to United States Salinity Laboratory (USSL) classifications lake water falls in medium salinity – low sodium category. Trophic State Index (TSI) indicates that the eutrophic nature exhibit in this lake. The ratio of total nitrogen and total phosphorus reflects that the lake is phosphorus dominant in respect of nutrient.

Keywords: Silicate minerals; United States Salinity Laboratory; Trophic State Index; Eutrophic; Nutrient; Saheb Bandh

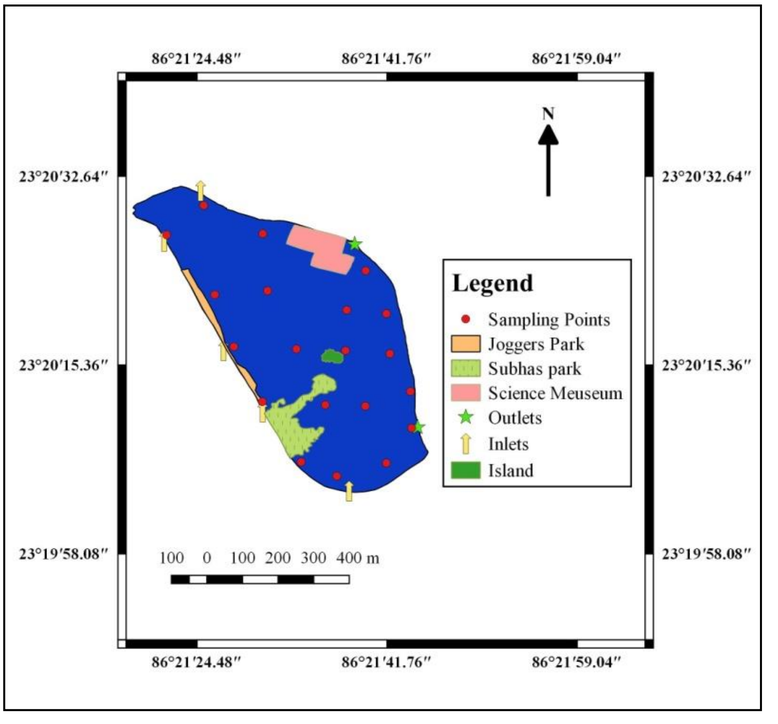
INTRODUCTION

Lakes are known to be ecological balance of the health of a town as they regulate the micro-climate of any area (Benjamin, et al., 1996), thereby influencing the people’s life adjacent to it. Lakes have a great effect on environment due to various reasons viz., sources of water, surface water recharge and discharge for drinking and irrigation, food and nutrition, recreation means education, boating, swimming, walking and jogging in the lake catchment area. Lakes are natural construction for climate change adaption and biological cycles, pisiculture, wildlife habitat, especially fishes and migratory birds and rain water harvesting (Ravikumar, et al., 2013).

The natural conditions of any lake ecosystem depend upon the nature of lake and its exposure to various environmental factors. Lake water quality depends not only on natural processes on anthropogenic influences(industrial, agricultural activities *etc*.) (Papatheodorou, et al., 2006). The Lakes and Reservoirs, all over the country without exception, are in varying degrees of environmental degradation which is due to eutrophication (due to the inflow of domestic and industrial effluents), encroachments, and siltation. There has been a huge jump in population during the last century without corresponding development of civic facilities resulting in lakes, especially the urban ones, becoming sinks for contaminants. Most of the urban and rural lakes are disperse under pressure with environmental concerns in worldwide (Iscen, et al., 2008).

Saheb bandh lake, located at the north-western part of the Purulia Municipality (23.33°N, 86.37°E), West Bengal was the initiative of the British Cornel Tikley (1843-1848) to eradicate the serious drinking water crisis of the area at that time. Till then Saheb bandh represents the lung of Purulia and is a vulnerable source of water for the drought prone town of Purulia. The lake has approximately 60 acres water area having the source of water from water table aquifer and also storm water runoff mixed with sanitary sewage from the catchment area during rainy season. Every year, at the height of summer, when the area faces an acute scarcity of drinking water, the residents of Purulia town are supplied water from this lake, though the administration has never been careful in maintaining the purity of its water or keeping its surroundings clean. Number of motor repairing shops, garages, nursing home, private apartments, housing complexes, hotels, bathing ghats, amusement park *etc*. have been cropped up surrounding the lake leading to discharge of nitrate and phosphate loaded waste water into the lake through inlets. Objective of the present research work mainly focused on lake hydrogeochemistry and its suitability for drinking and irrigation use. Apart from this, tropic state status of the lake has also been addressed in this study.

Figure 1 Study area along with sampling location details



METHODOLOGY

Altogether twenty water samples (Figure 1) were collected from the surface of the lake by means of a boat and GPS. Parameters like temperature, pH, EC, DO, BOD, TDS were measured in the field immediately after sampling. Major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^-, SO_4^{2-}, Cl^-), Chlorophyll-a (Chl-a) were analysed by APHA (1999) methods. The secchi disk transparency measurement was determined by the depth at which the black and white coated disk is no longer visible with the naked eye in the water column. Spatial interpolation of physic-chemical parameters and statistical analysis were done in Surfur 9 and XLSTAT 2015 software respectively.

Quality control and assurance

Proper care and management has been taken during sample collection and preservation. Mark reagents (AR grade) were used for preparation of solutions in laboratory analysis. Each analysis for collected water samples were three times replicated to ensure the precision of experimental results.

RESULTS AND DISCUSSION

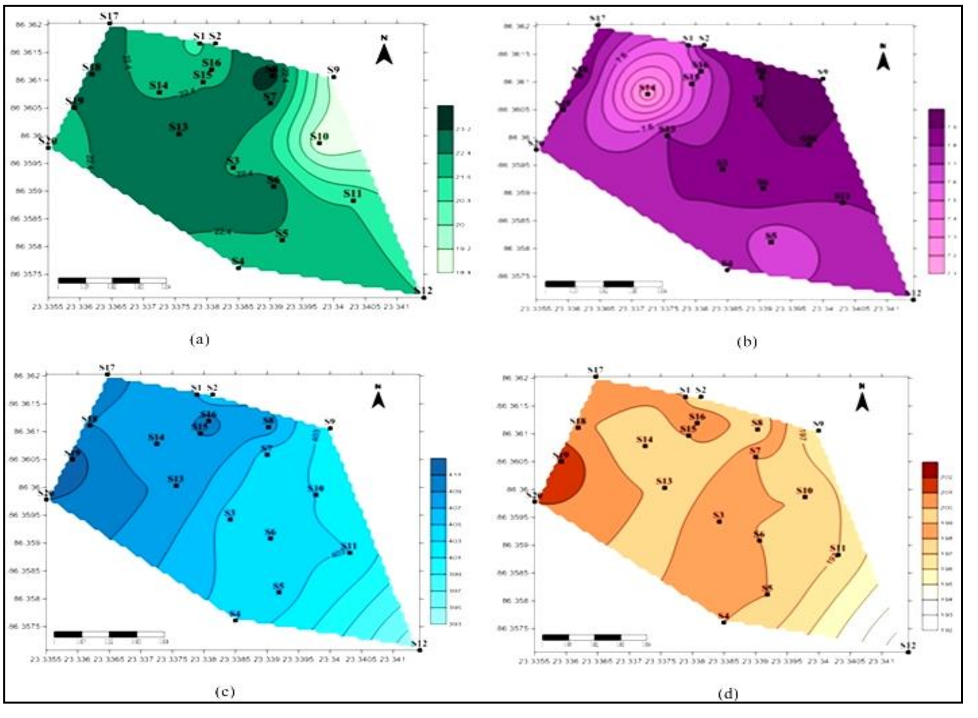
General Water Quality

The physico-chemical properties of water quality analysis give a proper evidence of the trophic state status, productivity and sustainability of a water body (Mustapha, 2008). The changes in the physico-chemical parameters provide valuable information and suggestions on the water quality, the source (s) of the variations and their effects on the functions and biodiversity of the lake water.

Temperature, pH, EC and TDS

Temperature plays an important role in the metabolic activities of the organism (Bade, et al., 2009). pH is a numerical expression that indicates the degree to which water is acidic or alkaline, with the lower pH value tends to make water corrosive and higher pH provides taste complaint and negative impact on skin and eyes (Rao & Rao, 2010). Electrical conductivity is a measure of ionic concentration of water is a direct function of its total dissolved salts (Harilal, et al., 2004) and is used to represent as an index of the total concentration of soluble salts in water (Gupta, et al., 2008). Saheb bandh lake has temperature, pH and EC in the range of 18.5 – 23.6 °C, 7.1 – 7.9 and 393 – 412 µS/cm, respectively. The maximum temperature is observed in the north-west-south portion of the lake (Figure 2(a)). Spatial distribution of pH (Figure 2(b)) reveals that eastern and western side of the lake is slightly alkaline because of the discharge of waste water from hospitals and households through inlets. Waste water of this source mostly have ionic compounds (salts) containing alkali metal or alkaline earth metal elements that form hydroxide ions (Encyclopaedia Britannica, 2014). In case of EC (Figure 2(c)), the similar result is observed like temperature. Total dissolved solids (TDS) mainly consists of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, potassium, sodium, iron *etc*. and small amount of organic matter. The range of the surface TDS is varying from 96 – 201 mg/L (Figure T(d)) which is below the BIS desirable and permissible limit of 1000 and 2000 mg/L (BIS, 1998). Maximum TDS is observed in west side (Figure 2(d)) of the lake, because of the influx of domestic waste water, bearing higher amount of inorganic salts and organic matter.

Figure 2 Spatial distribution of (a) Temperature, (b) pH, (c) EC and (d) TDS



Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Depletion of DO indicates water is polluted and DO levels in lakes vary according to their trophic levels (Srivastava, et al., 2009). Dissolved oxygen is necessary to sustain aquatic biota and provides a self purification capacity for water. In Saheb bandh lake DO content ranges from 4.37 – 8.37 mg/L (Figure 3(a)). Spatial distribution of DO reveals that middle portion of the lake has higher DO level (6 – 8 mg/L) than the periphery (<6 mg/L). In summer when temperatures is high then warmer water becomes saturated more easily with oxygen and it can hold less and less DO which suggest the organic pollutants are consumed by the aquatic pollutants (Wu, et al., 2014). Both BOD and COD are the indicators of organic contamination (Ravikumar, et al., 2013). BOD is a measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. COD is a measure of the oxidation of reduced chemicals in water and used to indirectly measure the amount of organic compounds in water (Kumar, et al., 2011). In the present study, BOD and COD of the lake water range from 0.51 – 6.14 mg/L and 26.88 – 188.16 mg/L respectively (Figure 3(b) and (c)). The maximum BOD and COD are found in north-south and north-west portion of lake because in this portion the waste water of residential, hospitals and garages origin is continuously discharged into lake thereby increasing COD level.

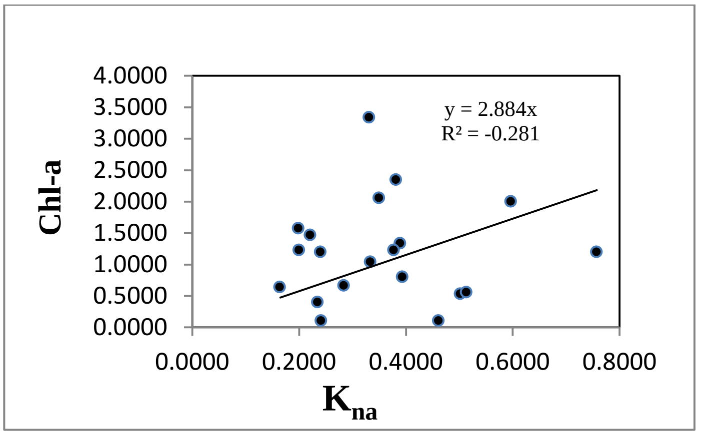
Chlorophyll-a

Chlorophyll-a is an indicator of lake water eutrophication (Wu, et al., 2017). The range of Chlorophyll-a in this lake is 0.107 – 3.338 mg/m^3 (Figure 3 (d)). Maximum chlorophyll-a is found in the periphery portion of this lake than the middle portion because suspended phytoplankton is found in higher concentration in that portion than the middle. Non-algal Light Attenuation Coefficient (K_{na}) is estimated in order to evaluate the mechanisms controlling light attenuation in the water column (Walker, 1982). The coefficient is generally controlled by four major factors that decrease light penetration in the water column: the water itself (a function of depth), algal biomass, non-algal particulate material (*i.e.*, volatile suspended sediment), and coloured dissolved organic matter (Ganju, et al., 2014). Non-algal light attenuation is calculated using the following equation:

$$K_{na} = \frac{1}{SD} - (0.025 \times Chl\ a) \text{ ....(i)}$$

In this study, chlorophyll-a has a negative correlation with K_{na} (Figure 4), which may be due to the dominance of light limiting factors such as presence of high turbid-water and inorganic solid in the lake.

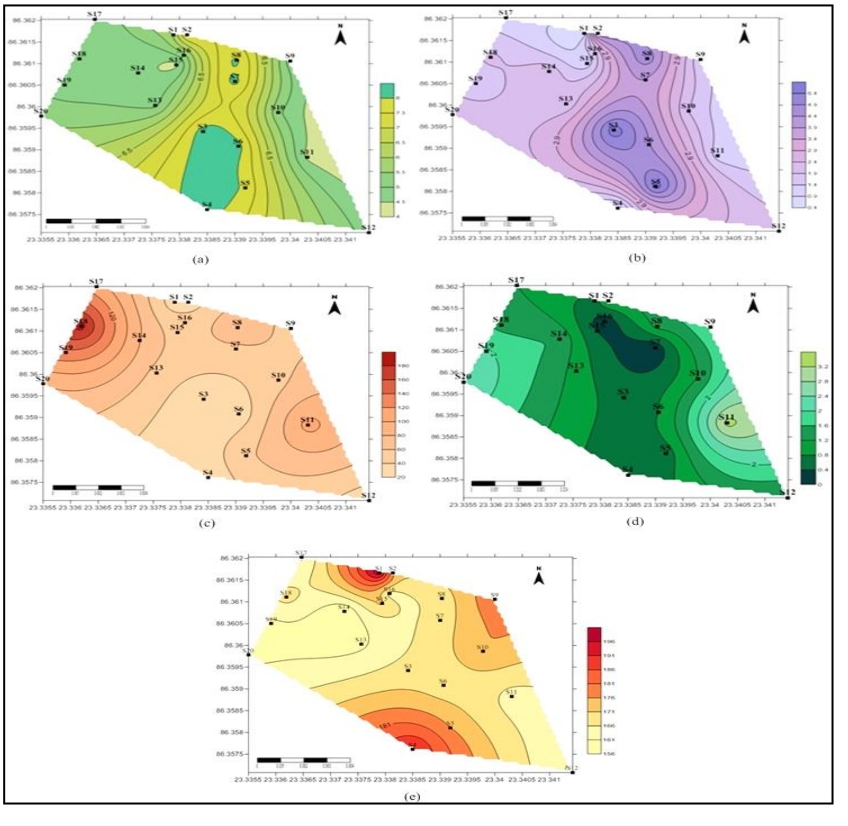
Figure 4 Scatter diagram of K_{na} vs Chl-a



Total Hardness (TH)

High total hardness may cause taste objection and negative impacts on human health (Arabi, et al., 2013). TH of the lake water ranges from 156 – 200 mg/L (Figure 3(e)) as $CaCO_3$ with a mean of 170 mg/L. According to WHO (2004) classification, lake water is classified as hard water (TH: 150 – 300 mg/L). Hard water may be originally derived from dissolution of carbonates, but evaporation (Wu, et al., 2017), discharge of garages, motor repairing shops, sewage run off from hospitals, housing complexes may have significant influences on it.

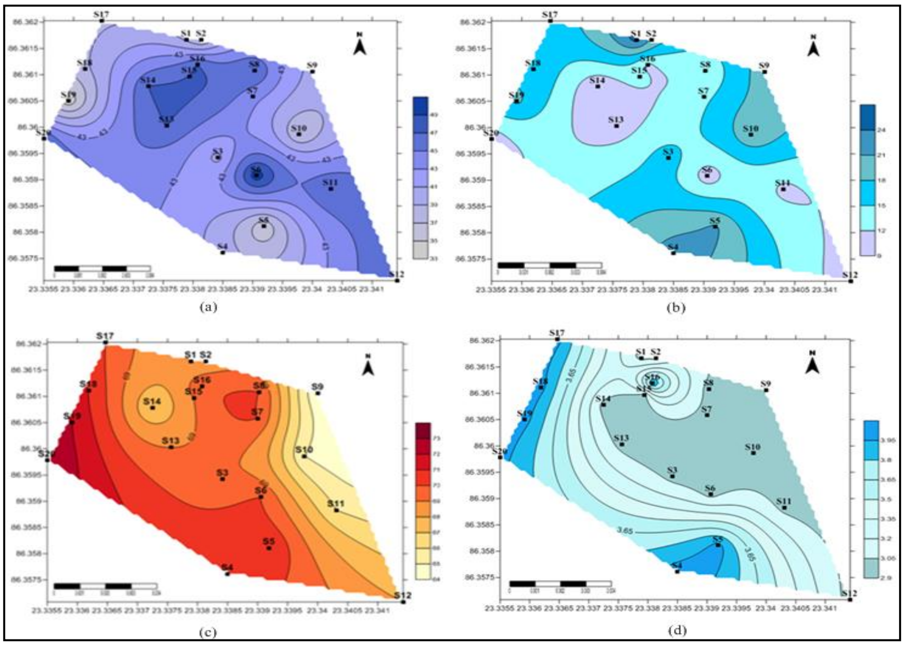
Figure 3 Spatial distributions of (a) DO, (b) BOD, (c) COD, (d) Chl-a and (e) TH



Major Cations

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) in lake water mainly occur from dissolution of carbonates (Wu, et al., 2017). In the present study, their concentrations are in the range of 33.6 – 50.4 mg/L and 9.37 – 25.23 mg/L (Figure 5(a) and (b)). Potassium (K^+) level in the lake water is almost constant i.e., 3 – 4 mg/L (Figure 5(d)). Potassium originates in lake water mainly from rock weathering and increases under intense evaporation (Wu, et al., 2017). Among all the cations, sodium (Na^+) is most abundant in the studied lake water. It ranges from 68 – 73 mg/L (Figure 5(c)) with a mean of 69 mg/L. All the cations are observed higher in the periphery of the lake than the middle. Based on the mean concentration, the abundance of cation is in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$.

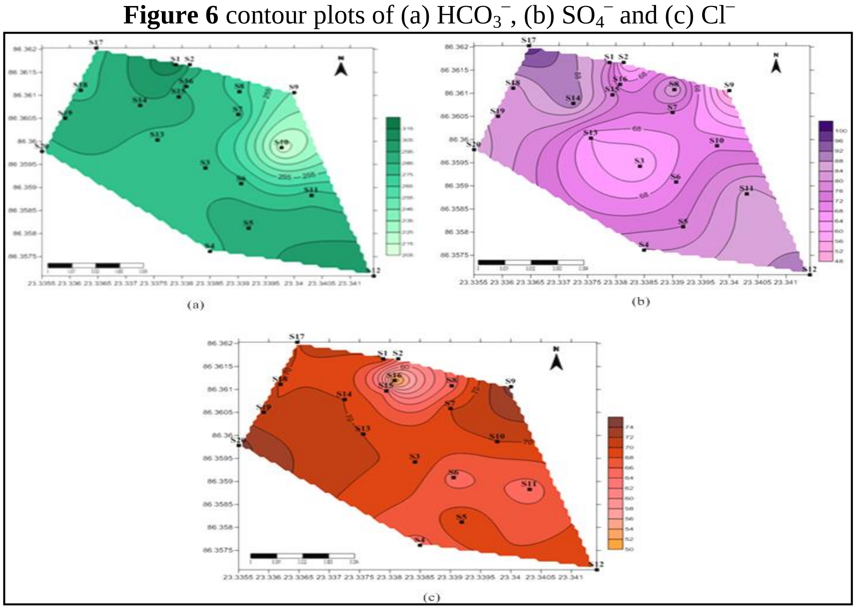
Figure 5 spatial distributions of (a) Ca^{2+}, (b) Mg^{2+}, (c) Na^+ and (d) K^+



Major Anions

In case of anions, HCO_3^- concentration is the highest among all the anions, which range from 244 – 317.2 mg/L (Figure 6(a)). The SO_4^{2-} range is detected in lake water is 47.86 – 91 mg/L (Figure 6(b)) which is below the desirable limit according to BIS (1998). Chloride (Cl^-) is evenly distributed throughout the lake, ranging from 64.98 – 74.98 mg/L (Figure 6(c)). According to mean concentration, the abundance of major anions in the lake water is $HCO_3^- > SO_4^{2-} > Cl^-$.

Figure 6 contour plots of (a) HCO_3^-, (b) SO_4^- and (c) Cl^-

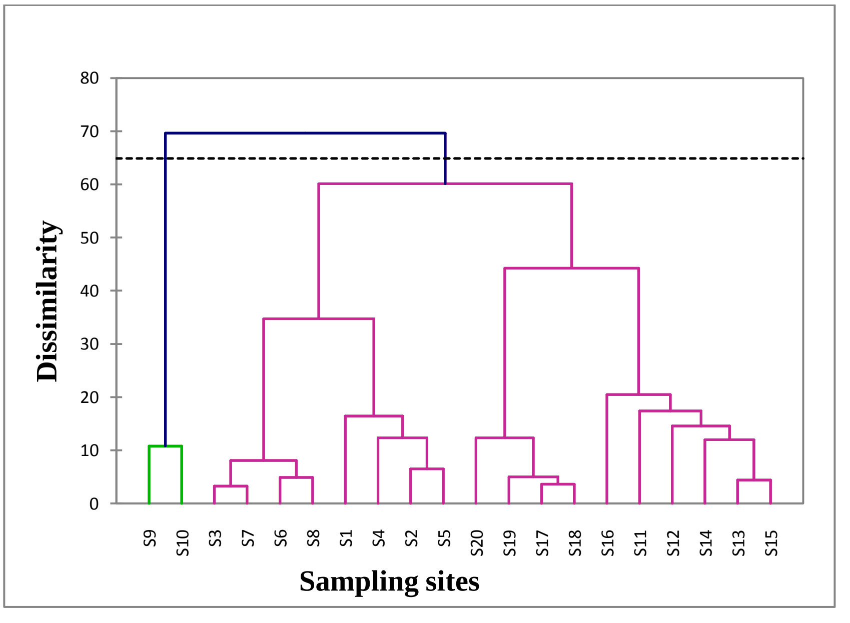


Cluster Analysis

Hierarchical agglomerative clustering is the most common approach, which provides spontaneous similarity relationships between any one sample and the entire data set and is typically illustrated by a dendrogram. The dendrogram provides an image summary of the clustering processes, presenting a diagram of the groups and their closeness, with a dramatic reduction in dimensionality of the original data (Shrestha & Kazama, 2007).

A dendogram of sampling sites, obtained by Ward's method is shown in Figure 7. Cluster analysis is used to detect dissimilarity groups between the twenty sampling sites. There are two statistically significant clusters are formed. Cluster 1 (sampling sites 1 – 8, 11 – 20) is mainly concentrated in the middle and periphery portion of the lake. Among these sites few sampling points lie near to inlets. Cluster 2 (sampling sites 9 and 10) which also lie at the periphery portion of the lake but near to outlet of the lake. Saheb bandh lake is open lake system with existing five inlets and two outlets. It is known that huge amount of waste generated in surrounding the lake may find their way into surface water of lake when carried out by runoff from rain water, effluents discharge from garages-nourishing home and municipal sewage. Water in lake may carry large amounts of matter comprising inorganic, organic and dissolved matter, any other matter that the water unsuitable for direct use (Iscen, et al., 2008). Present study reveals that there is a difference in the physico-chemical properties of cluster 2 and cluster 1.

Figure 7 Dendogram based for agglomerative hierarchical clustering (Wards method)



Lake water type and hydrogeochemical processes

Water Type

The chemistry of surface water samples are plotted as trilinear piper diagrams (Figure 8) and is explained in Table 1. The Piper-Hill diagram (Piper, 1953) is generated by using AquaChem software and is used to infer hydro-geochemical facies. The percentage of samples falling under magnesium bicarbonate type (Figure 8) is 90 *i.e*., the chemical properties of the water are dominated by alkaline earths and weak acids and the percentage of the samples falling under mixed type is 10 *i.e*., no one cation-anion pair exceeds 50 %.

Mechanism controlling lake water chemistry

The hydrogeochemistry of lake water is mainly controlled by the chemical constitution of sewage runoff, water-rock interaction phenomena, manmade and anthropogenic activities in the lake water. Gibbs (1970) diagram (Figure 9) shows that all water samples are plotted in the rock dominance zone of the diagrams suggest that rock-water interaction as a dominant factor in dictating lake water hydrogeochemistry of the study area.

Figure 8 Piper diagram showing water type of the lake water

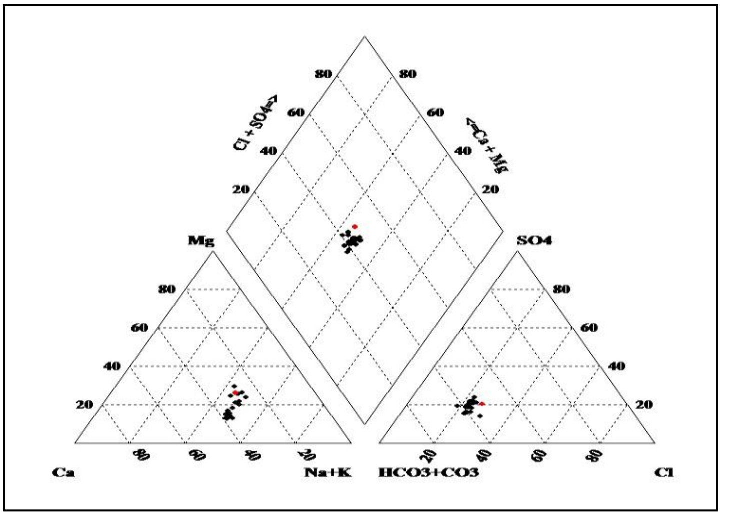
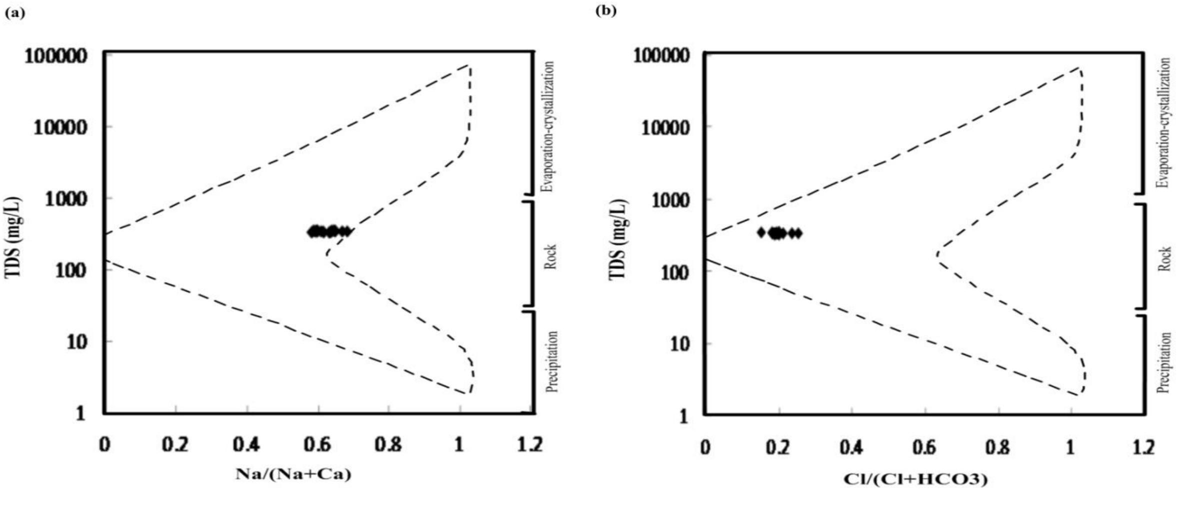


Table 1 Water type and % of distribution of lake water sample in each category

Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category
1	Alkaline earths (Ca+Mg) exceeded alkalies (Na+K)	90
2	Alkalies exceeded alkaline earths	10
3	Weak acids (CO_3+HCO_3) exceeded strong acids (SO_4+Cl)	100
4	Strong acids exceeded weak acids	0
5	Magnesium bicarbonate type	90
6	Calcium-chloride type	0
7	Sodium-chloride type	0
8	Sodium-Bicarbonate type	0
9	Mixed type (No cation-anion exceed 50%)	10

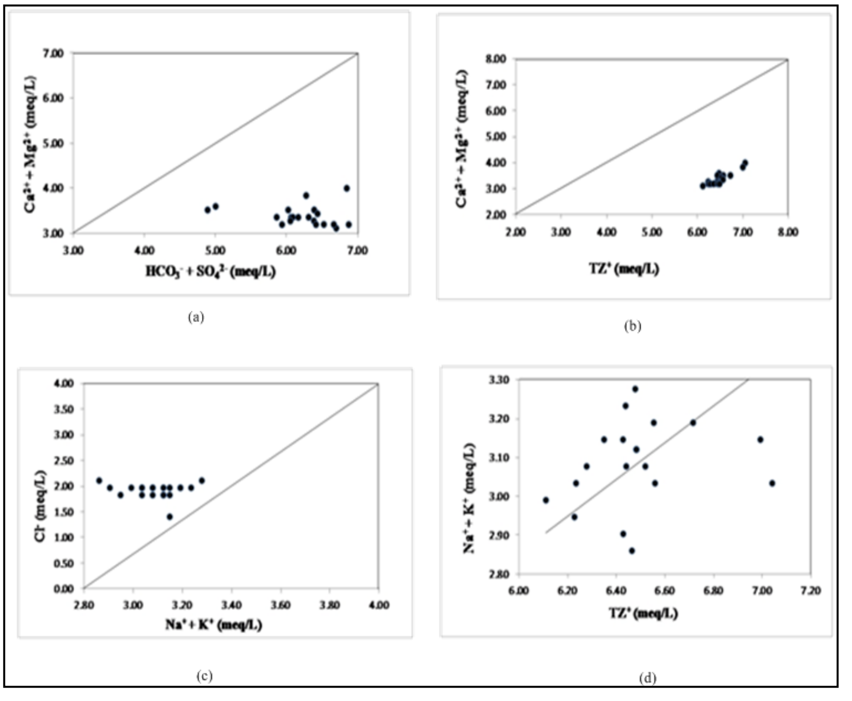
Figure 9 Gibbs diagram representing the ratio of (a) $Na^+/(Na^++Ca^{2+})$ and (b) $Cl^-/(Cl^-+HCO_3^-)$ as a function of TDS (Gibbs, 1970)



Watershed weathering and erosion are the prime importance in controlling lake-water chemistry. Evidences of silicate weathering can be explained by the relationships of HCO_3^- + SO_4^{2-} versus Ca^{2+} + Mg^{2+} (Figure 10(a)). The scattered plot indicates that 100 % of the samples lie below the equiline of 1:1 which indicates the dominance of silicate weathering. The Total cations (TZ^+) vs (Ca^{2+} + Mg^{2+}) shows that the data lie far below the theoretical line (1:1) (Figure 10(b)), depicting an increasing contribution of alkalis to the major ions and also reflecting an increasing contribution of Na^+ and K^+ with increasing dissolved solids. The concentration of

(Na^{+}+K^{+}) in the analyzed water samples is significantly in excess over Cl^{-} and high (Na^{+}+K^{+})/Cl^{-} ratio, *i.e.*, 1.62 suggests that much of the alkalis originate from the source other than precipitations and probably from the weathering of silicates (Figure 10(c)). The Total cations (TZ^{+}) vs Na^{+} + K^{+} scatter diagram (Figure 10(d)) of the study area shows sample points falling both along and above the Na^{+} + K^{+} = 0.5 Total cations. This suggests that the cations in the lake water might have been derived from silicate weathering (Datta & Tyagi, 1996).

Figure 10 Scatter Diagram of (a) HCO_3^{-} + SO_4^{2-} vs Ca^{2+} + Mg^{2+}, (b) TZ^{+} vs Ca^{2+} + Mg^{2+}, (c) Na^{+} + K^{+} vs Cl^{-} and (d) TZ^{+} vs Na^{+} + K^{+}



Water Quality Index (WQI)

Water quality index means overall measurement of water quality by a single number. WQI is calculated by using 'Weighted Arithmetic Index' method (Brown, et al., 1970) which involves the estimation of 'unit weight' assigned to each physico-chemical parameters considered for this calculation. Out of the thirteen parameters, BOD is found to be the highest influencing parameters in WQI scores (Table 2). The final WQI value is 61.75 that means the lake water is poor for drinking purpose (Table 3) and can be possible used for irrigation and industrial purpose.

Table 2 Relative weights (*Wn*) of the parameters used for WQI determination (Bora & Goswami, 2016)

Parameters	ICMR/BIS standard (V_s)	Quality Rating (Q_n)	*Unit Weight* (W_n)	Q_nW_n
pH	8.5	50.67	0.1484	7.5168
EC	300	20.29	0.0006	0.0128
TDS	500	34.10	0.0013	0.0430
TA	120	116.00	0.0063	0.7314
TH	300	56.60	0.0042	0.2379
Ca^{2+}	75	56.67	0.0168	0.9528
Mg^{2+}	30	51.67	0.0420	2.1718
Na^{+}	100	69.00	0.0126	0.8701
K^{+}	10	33.50	0.1261	4.2245
Cl^{-}	250	27.19	0.0050	0.1372
SO_4^{2-}	150	38.21	0.0063	0.2409
DO	5	99.77	0.2102	20.9684
BOD	5	84.67	0.4203	35.5892
Total			**1.0002**	**73.6966**

All the parameters are in milligrams per liter except pH and EC (µS/cm)

Table 3 WQI range, status and possible usage of the water sample (Brown, et al., 1972)

WQI	Water Quality Status (WQS)	Possible usage
0 – 25	Excellent	Drinking irrigation and industrial
26 – 50	Good	Drinking irrigation and industrial
51 – 75	Poor	Irrigation and industrial
76 – 100	Very poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

Irrigation Water Quality

In the present study, lake water quality is assessed for irrigation purpose on the basis of Sodium Adsorption Ratio (SAR), Residual Sodium Carbonates (RSC), Permeability Index (PI) and Magnesium Hazards (MH) (Aghazadeh, et al., 2016; Dhanasekarapandian, et al., 2016; Li, et al., 2016b, c; Sharma, et al., 2016; Wu & Sun, 2016).

Sodium Absorption Ratio

SAR represents the sodium hazard to crops which is caused by excessive Na^+ in irrigation water (Alam, 2014; Li, et al., 2016a). SAR calculated as the relative proportion of Na^+ to Ca^{2+} and Mg^{2+} ion concentrations in a water sample with expressed in meq/L.

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}} \quad \text{...(ii)}$$

Water with SAR less than 10 is considered excellent for irrigation, while SAR higher than 26 indicates unsuitable for irrigation purposes (Wu, et al., 2017). SAR of the studied lake water ranges from 2.07 – 2.50, indicating excellent for irrigation purpose.

Residual Sodium Carbonate (RSC)

RSC can be calculated as the following formula with ions expressed in meq/L.

$$RSC = (HCO_3^- + CO_3^-) – (Ca^{2+} + Mg^{2+}) \quad \text{...................................(iii)}$$

Water with RSC less than 1.25, 1.25 – 2.50 and greater than 2.50 are considered safe/good, marginal/doubtful, unsuitable for irrigation, respectively (Richards, 1954). With respect to RSC of Saheb Bandh lake water, 45 % samples are good and 55 % samples fall under marginal/doubtful category. Application of lake water with this sort of RSC may cause alkaline hazards to soils (Wu, et al., 2017).

Percent Sodium (Na %)

According to Wilcox (1955), in all natural waters Na % is a common parameter to assess its suitability for irrigational purposes. The sodium percent (Na %) values were obtained by using the following equation and expressed in meq/L:

$$Na\ \% = \frac{Na^+}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}} \times 100 \quad \text{...(iv)}$$

Water with percent sodium (Na %) less than 20 is considered excellent, 40 – 60 is considered permissible and greater than 80 is considered unsuitable for irrigation (Wilcox, 1995). In this case, % Na value computed as 41.83 – 48.90 which indicates all the samples come under permissible category.

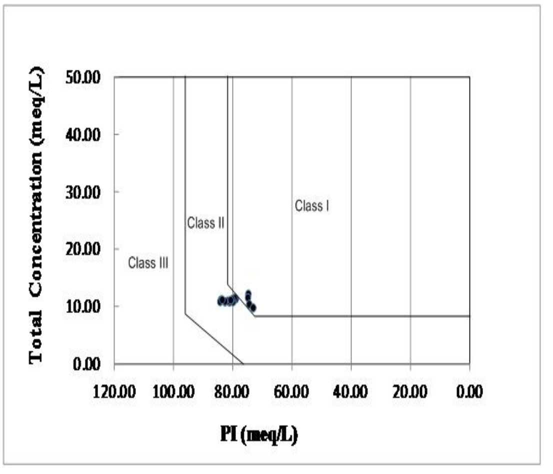
Permeability Index (PI)

Long-term use of irrigation water may affect soil permeability (Li, et al., 2016c). Permeability Index is usually used to represent the chance of effect of irrigation water or soil property (Wu, et al., 2017). This index is calculated by following formula and expressed in meq/L.

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Na^+ + Ca^{2+} + Mg^{2+}} \times 100\ \% \quad \text{...(v)}$$

According to Doneen (1964) a criterion for assessing the suitability of irrigation water based on PI. Water classified into class I is considered 100 % maximum permeable and excellent for irrigation, class II is considered 75 % maximum permeability and is marginally suitable for irrigation, and water in class III is associated with only 25 % maximum permeability and is regarded unsuitable for irrigation (Li, et al., 2016c; Sharma, et al., 2016).

Figure 11 Doneen classification of irrigation water based on Permeability Index



As shown in Figure 11, 20 % of studied lake water samples fall into class I, indicating excellent quality and 80 % samples fall into class II, indicating marginally suitable for irrigation water.

Magnesium Hazard (MH)

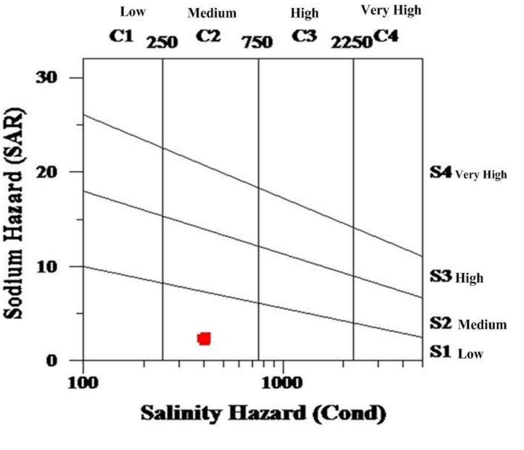
Calcium and magnesium ion maintains an equilibrium state in most of the water. In equilibrium, Mg^{2+} in waters will adversely affect crop yield (Nagaraju, et al., 2006). Magnesium hazard was developed by Paliwal (1972) and expressed in meq/L. Magnesium Hazard of less than 50% is suitable for irrigation and more than 50% is unsuitable for irrigation practice and the soil becomes more alkaline (Ayers & Westcot, 1985).

$$\text{Magnesium ratio} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad \text{..(vi)}$$

In case of studied lake water the MH values fall in the range of 24.92 to 52.11 %. 90 % of the samples shows MH ratio<50 % (suitable for irrigation) while 10 % falls in the unsuitable category.

United States Salinity Laboratory (USSL) diagram considers the alkalinity and salinity of irrigation water simultaneously (USSL, 1954). Water with EC lower than 250 µS/cm is excellent for irrigation and higher than 2250 µS/cm is poor for irrigation (USSL, 1954). In this study, all lake water samples are plotted in C2S1 zone (Figure 12) suggesting that the lake water is medium salinity - low sodium hazard *i.e.*, moderately suitable for irrigation in terms of salinity.

Figure 12 USSL classification of lake water



Trophic state status

Trophic state is defined as the total weight of living biological material in a water body at a specific location and time. This method transforms the trophic state variables (total phosphorus, chlorophyll-a, secchi depth) to a Trophic State Index (TSI) ranging from approximately 0 – 100 which represents the trophic state of a lake (Carlson & Simpson, 1996). The Trophic State Index (TSI) was calculated using the following formulae:

1. TSI for secchi disk depth (SD) = 60-14.41 × Ln SD meters

2. TSI for chlorophyll a (Chl-a) = 9.81 × Ln Chl a, μg/l + 30.6

3. TSI for total phosphorus (TP) = 14.42 × Ln TP μg/l + 4.15

The final Carlson Trophic State Index (TSI) is calculated by following formula:

CTSI = [TSI(SD) + TSI(Chl-a) + TSI(TP)] /3

where, TSI-TP = Trophic state index referenced to total phosphorus, (TP) = represent total phosphorus (μg/L), TSI-SD = trophic state index referenced to secchi depth, SD = represents secchi depth in meters, TSI-CHL = trophic state index referenced to chlorophyll-a, CHL-a = chlorophyll-a (μg/L), while Ln = natural logarithm.

In this lake CTSI value is observed as 55.73 *i.e.*, the lake is in eutrophic condition (Table 4), as a result transparency is decreased. Pearson correlation co-efficient reveals that TSI (SD) and TSI (Chl-a) (r=0.147), TSI (SD) and TSI (TN) (r=0.640), TSI (Chl-a) and TSI (TN) (r= 0.169) are positively correlated (Table 5). The ratio of total nitrogen (TN) and total phosphorus (TP) is used for estimating which nutrient limits for algal growth (Hou, et al., 2013). Low TN:TP ratio (less than about 10:1) is the indicator of nitrogen limitation, whereas ratio greater than 10:1, indicates increasing of phosphorus limitation. In the present study reflects that the average TN:TP ratio is 25.99, characterizing the phosphorus to be the limiting nutrient in lake. This low ratio is typically indicates that the very high TP loads coming from point sources which is situated surrounding the lake.

Table 4 Carlson's Trophic State Index values and classification of lakes

TSI values	Trophic Status	Attributes
< 30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes will become anoxic during the summer
40- 50	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
50-60	**Eutrophic**	**Lower boundary of classical eutrophy: Decreased transparency, warm-water fisheries only**
60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
70-80	Eutrophic	Heavy algal blooms possible throughout the summer, often hypereutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes

Table 5 Correlation table of TSI(SD), TSI(Chl-a) and TSI(TN)

Variables	TSI(SD)	TSI(Chl-a)	TSI(TN)
TSI(SD)	**1**		
TSI(Chl-a)	0.147	**1**	
TSI(TN)	**0.640**	0.169	**1**

CONCLUSIONS

The present study is carried out in order to determine the hydrogeochemistry, water quality and suitability for irrigation purposes and trophic state determination. In this study, interpretation of hydrogeochemical analysis reveals that the lake water in area is medium to hard. Distribution of lake water samples in Piper diagram reveals that most of the samples are under the magnesium-bicarbonate category. Weathering of silicate is generally considered to be the major source of HCO_3^- and SO_4^{2-} in the lake water. Cluster analysis grouped twenty sampling sites into two clusters according to dissimilar water quality characteristics. All samples in lake water sources belongs to C2S1, indicating medium salinity – low sodium water, which can be used for irrigation on all types of soil without danger of exchangeable sodium. According to TSI-SD, TSI-Chl-a, TSI-TP suggested that Saheb bandh lake exhibit a eutrophic condition, so that, this lake is very nutrient-rich characterized by frequent and severe nuisance algal blooms. This present investigation revealed that one of the most important causes of water pollution is discharge of untreated water from inlets without adequate attention to suitable management of sewage and waste material. So the untreated water should be treated before mixing into the lake and also should be taken up some initiative steps to restore the lake in its productive condition by the Purulia municipality.

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